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A Review of Wheat Quality Assessment

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ABSTRACT
Wheat (*Triticum aestivum*) is ranked as a staple food for the people of all over the world. Wheat is grown in a wide range of environments that affect overall performance, predominantly grain yield and end-use superiority. Wheat yield and end-use quality depend upon the environment, genotype and their interaction. The milling business requires to amass the different wheat types separately on the basis of their end-use properties and to blend properly the grain to get hold of the optimal flour for the particular processing of interest. It is therefore clear that the classification of the different lots of wheat is a crucial matter to determine its quality. Different factors determine wheat quality. The quality of wheat is generally assessed on the basis of different physical, chemical and rheological properties. The products prepared from wheat grains require different quality characteristics. So in this comprehensive review we will discuss about the physical, chemical and rheological characteristics of wheat which affect its quality to select the more important for bread and chapatti making.

INTRODUCTION

The quality of wheat is affected by many intrinsic and extrinsic factors. The wheat quality is a result of the cumulative effects of soil, climate and seed stock in the wheat plant and its kernel component. The term wheat quality is a complex of many factors and cannot be defined in terms of a single attribute but depends on several milling, chemical, baking and rheological dough properties.

The quality of wheat has different meanings depending on its intended use and same applied when deciding the quality of wheat. The criteria of wheat quality varies with its varying usage and suitability of wheat for one specific purpose may not fulfil the demand or producing un-satisfactory results for another use [1]

The wheat quality has been defined simply by Finney *et al.* [2] as in terms of its suitability for a particular purpose or use. Wheat desirable for a specific use or purpose has good quality and that is not desirable has poor quality. Likewise, Kent and Evers [3] have also explained in detail about different meanings of the wheat quality. They reported that wheat passes through many hands from field to table; all those who handle it are interested in the quality of cereals, but in different ways. The grower requires good cropping and high grain yields. The miller requires wheat grains of good milling quality-fit for storage, and capable of producing the maximum yield of flour suitable for a particular purpose. The baker requires wheat flour suitable for baking e.g., bread, biscuits or cakes. He also wants his flour to yield the maximum quantity of goods which meet rigid specifications, and therefore, requires consistency in the quality of raw material. The consumer reliance is set on sensorial attributes of the final product and demand for better palatability and good appearance in the baked goods with high nutritive value at reasonably priced.

The requirements of wheat grain quality are different for the major baked products such as bread, pastries and cookies and also within each of the types of these baked products. The overall bread making quality of wheat depends on several factors such as water absorption, loaf volume, internal and external loaf characteristics and tolerance to mixing and fermentation and these characteristics are correlated to the physical and chemical characteristics of wheat flour and dough [4]. The physical characters include grain appearance score, kernel hardness, vitreousness of kernel, kernel weight, test weight, kernel size and shape. The chemical characters include protein content, protein quality (gluten content), sedimentation test and other tests such as farinograph, extensograph, mixograph and alveograph which can asses the mixing or visco-elastic properties of the dough [5]. Other bread making quality tests like the Pelshenke dough ball test and the SDS (sodium dodecyl sulphate) sedimentation test can also provide valuable information about the baking quality of wheat.

Cornell and Hovelling [6] were of the view that wheat quality could be usually assessed on the basis of the ability of the wheat flour to produce a high standard loaf of bread, (yeast leavened bread). They further reported that wheat quality is influenced both by genetic and agronomic practices and its assessment can be divided into tests based on physical and chemical criterion.

The important quality attributes for describing wheat quality are flour extraction rate, protein content, amylase activity and etc. which are affected by varieties, environments in which they are grown and the environment x genotype interactions [7].

A number of research workers have associated cooking quality of pasta with protein content, gluten composition and solubility, farinograph mixing characteristics, SDS-sedimentation volume and mixograph characteristics [8]. However, the kernel hardness and gluten proteins are also the two major determinants of the wheat quality [9]. Protein quality is again dependent upon glutenin and gliadin contents and their respective proportionality [10]. Molecular basis of glutenin sub-units is important in determining the wheat quality in terms of its end use [11]

Cox *et al.* [12] and Pates [13] reported that in mid eighteens a concern was generated in the baking industry regarding a decline in end use quality of wheat due to the improvement in grain yield achieved in hard red winter wheat. However, this concern was ruled out by Cox *et al.* [12] who concluded in a research study that any decline and deterioration in the quality of hard red winter wheat perceived by the baking industry has been caused by the non genetic factors such as changes in environment, milling practices and commercial baking methods and formulations or a combination of these factors.

The wheat quality evaluation by the use of analytical methods may determine both the quality and quantity of wheat proteins using high-resolution techniques such as: SDS-PAGE, low pH PAGE [14] and RP-HPLC [15]. However Tronsmo *et al*. [16] explicated that baking tests are more elaborative in explaining the end use of quality of wheat and among loaf volume is of major importance.

FACTORS AFFECTING WHEAT QUALITY

Variety is an important factor influencing the wheat grain quality; generally wheat is marketed according to the class where as each class consists of group of varieties with similar characteristics and is suited for similar purposes/ end uses [1]. The wheat grain quality have been broadly classified in to two groups; physical characteristics such as vitreousness (correlated with hardness of grains, which indirectly is an index of protein and gluten content), color (two basic colors red or white used for wheat grading purposes), grain weight (function of grain size and density and more reliable to estimate the flour yield), grain size, and shape (closely related to grain weight and affect the flour yield), grain hardness (major factor for grain quality and used in differentiating hard and soft classes of wheat) and chemical characteristics such as moisture content (effects keeping quality of wheat), protein content (major determinant of wheat quality, higher the protein higher the price of the wheat), amylase activity (negative effect on bread making quality), crude fiber and ash content (inversely related to the flour yield and are related to amount of bran in wheat grain). Other factors like class, environment i.e. climate, soil and cultural practices also affect the composition of the wheat grain [17]. These all quality factors are influenced by genetic makeup, environment and cropping patterns. Both genotype and environment greatly influenced Chinese steam bread quality [18]. Peterson *et al.* [19] also reported significant effect of genotype, environment, and interaction effects on the quality of all parameters. They concluded that environmental influences on end-use quality attributes should have an important consideration in cultivar improvement efforts toward enhancing marketing quality of hard red winter wheat. Payne *et al.* [20] observed the changes in weight, volume, water content and anatomical structure of grains for three heavy grained and three light grained cultivars of spring wheat throughout the period from grain set until ripening. They found that grain weight was significantly affected as a function of dry matter accumulation and increase in grain volume.

Lill and Purchase [21] noted a larger influence of cultivars relative to the year for test weight and grain protein content. The variance ratio of cultivar to cultivar by year interaction indicated that cultivar effects accounted for most of the variability in grain protein yield, sedimentation volume, flour yield, falling number, mixograph dough development time, farinograph dough development time, farinograph stability and baking strength index. Susceptibility to interaction with year effects was observed for yield, starch yield, flour color, flour protein content and farinograph water absorption.

Faridi *et al.* [22] reported that individual farming practices also influence the quality of wheat and flour. Planting time of wheat can alter disease susceptibility, which in turn affects the wheat quality. If wheat is harvested at too high moisture content, incipient seed germination can result and may be detrimental to the quality of some cookies and crackers. Peltonen and Virtanen [23] found that application of nitrogen fertilizer improved bread making quality of low molecular weight proteins *i.e*. gliadins.

The major storage proteins in wheat are the gliadins and glutenins. Gliadins are subdivided into α, β, and ω units and glutenins into low and high molecular weight sub units (LMW-GS and HMW-GS). Weegels *et al.* [24] and Martinant *et al*. [25] also explained the genetic control and the relationships between gluten protein composition and quality characteristics.

Pechanek *et al.* [26] reported that application of high amount of nitrogen led generally to a significant increase in total protein content of grain. As total protein content increased, the ratio of low molecular weight (LMW) to high molecular weight (HMW) glutenins decreased consistently, i.e., in all varieties, in both years and locations. Changes of LMW: HMW ratio showed a significant negative correlation to sedimentation value and bread loaf volume. These results suggested that ratio of HMW glutenin, especially x-type subunits, to total protein content could be the best early detectable parameter with high predictive value for bread making quality. Veraverbeke *et al*. [27] reported that addition and incorporation of HMW-GS increased maximum resistance (MR) and extensibility (EX) when LMW-GS and HMW-GS for

dough extensibility were evaluated. The addition of glutenin subunits can be partially incorporated into the glutenin network in the presence of oxygen.

Overall, significant variation has been observed due to the effects of genotypes, environment and their interaction in different research investigations; milling [17], protein content [19, 28] and baking quality [17, 19, 29]. Gaines *et al*. [17] have also reported a strong effect of environment on grain conditions, which ultimately influence the milling and baking characteristics of wheat flour. Lafiandra *et al.* [30] attributed seasonal changes in wheat grain quality to be associated with high temperature during grain filling stage.

The improper handling at milling operations could also results in loss of wheat quality as errors such as sampling, incomplete removal of foreign material, inconsistent or inappropriate tempering, variation in ambient conditions, condition of milling equipment, improper mill settings, and inadequate standardization of procedures could results in valuable loss in wheat quality [8].

Tempering at level of higher moisture contents could decrease the flour extraction rate and ash contents while improving the flour color [31]. The variation in setting appropriate moisture contents for milling depends on the type of wheat as hard wheats require higher tempering moisture and tempering time to reach prime milling conditions [31, 32]. Habernicht *et al.* [33] found negative effect on end use quality of hard red and hard white spring wheats contaminated with grain of contrasting classes. Curioni *et al.* [34] described that the bread types could be distinguished solely by crumb grain characteristics. Sivri *et al.* [35] concluded that pre harvest bug damage to wheat can cause significant losses in bread making quality which frequently occurs in most countries of Middle East.

Baking quality of wheat is primarily affected by storage proteins (i.e. gliadins and glutenins) and both qualitative and quantitative characteristics of these proteins are considered when attempting to explain the quality variation observed among different wheat cultivars [36].

PHYSICAL CHARACTERISTICS

Wheat is often assigned a numerical scale, which depends upon the results of certain tests comprising test weight, kernel weight, percentage of damaged kernels and the percentage of foreign matters and dockage which are usually used in wheat grading systems.
The two important physical parameters are briefly reviewed here.

Test weight

Halverson and Zeleney [1] demonstrated that physical tests and observations regarding wheat actually described some of the characteristics. The weight of wheat grains per unit volume or test weight is one of the simplest and most widely used criterions of wheat quality. Kernel weight is a function of both kernel size and kernel density. Though kernel size is an inheritance characteristic but it is also affected by growing conditions [1, 37].

Monsalve-Gonzalez and Pomeranz [38] have reported that the test weight determines the milling properties such as flour yield and milling score. Hlynka and Bushuk [39] found that kernel shape, and uniformity of kernel size and shape are important factors affecting test weight besides other important factor influencing the test weight is the density of the wheat grain. Shuey [40] found positive correlation coefficient of 0.744 between test weight and flour yield. He was further of the view that though this relationship is significant but the test weight can not be considered a highly accurate or reliable predictor of flour yield. However, latter on Schuler *et al.* [41] described that test weight was not correlated with flour yield, but was significantly correlated with flour protein content ($r=0.54$ $P< 0.05$) as was kernel density ($r=0.49$). Hook [31] concluded that correlations between test weight and flour yield were poor. Marshall *et al.* [42] found that the relationship between test weight and milling yield was dependent on both the site and variety used, and therefore was not a reliable predictor of milling yield. There are conflicts in statements about the dependability of test weight to assess milling quality i.e. flour yield [2, 31]. Donelson *et al*. [43] rapidly measured the specific gravity (cm^3g^{-1}) of small (20 and 40g) samples of soft wheats and compared with bulk density ($g\ cm^{-3}$) measurements (micro test weights).

Thousand kernel weight

Thousand grain weight is the weight in grams of 1000 kernels of wheat. Since it is not volume based it is independent of some factors influencing bulk density, and may be preferred as a measure of grain quality. Wheat kernels can be classified according to grain weight as 15-25 g (very small), 26-35 g (small), 36-45 g (medium), 46-55 g (large) and over 55 g (very large) [37]. The thousand kernel weight varied from 42.4 to 48.7g in 128 wheat varieties [44], while Anjum *et al.* [45] found the kernel weight range from 31.43 to 37.28 g in different Pakistani wheat varieties. Thousand kernel weight is a component of grain yield along with spikes per unit area and number of kernels per spike. Kernel weight is determined by electronic seed counter and balances which are considered to be more reliable guide of flour yield than test weight. Kernel weight generally varies from 20- 45 grams per 1000 kernels,

based on the type of wheat i.e. hard or soft grains. Schuler *et al* [41] have shown that thousand kernel weight had no relation to milling qualities of soft red winter wheat. Baril [46] reported that thousand kernel weight within a genotype was positively correlated with agronomic yield.

CHEMICAL CHARACTERISTICS

Moisture content

The moisture content is one of the most important factors for the determination of wheat grain quality. Moisture content is inversely related to the dry matter of grain and has more effect on keeping quality of wheat as dry and sound wheat grains that can be kept for years when it is stored properly but wet wheat grains with higher moisture content may deteriorate faster in few days [47]. Storage of wheat grains with high or extremely low moisture contents often contributes towards losses in its quality. Usually, the moisture content of flour could vary from 11 to 15% depending upon the storage conditions and hygroscopic nature of the starch [48]. Various researchers have shown that the moisture content varied from 8.19-11.94 % [49, 50]. Cornell and Hoveling [6] have demonstrated that moisture contents of wheat are not only of economic significance but are also important with regard to the keeping qualities of wheat. They further stated that wheat of very low moisture is brittle and of high moisture content (>13.5%) has a tough character. The moisture content can be determined by using oven drying method (gravimetrically), but now more common method is to use a calibrated infra-red spectrophotometer (NIR) machine [47, 51].

Ash content

The purity of flour is assessed by the amount of ash in flour. Ideally the ash content in flour should range between 0.40- 0.45%. A combination of high extraction and low ash is an indicator of efficient milling of wheat. The ash content may vary from 0.48-0.54% in wheat milled through short milling system by the Quadrumate Junior Mill. However, combination of 70% extraction flour with 0.48% ash would indicate efficient milling and good mill ability of the wheat. The Quadrumate can give an excellent 72-73% extraction of flour. The ash content ranged from 0.6 to 0.8% for extractions of 80% or more in Middle East flour [37].The ash content reported by various researchers varied from 0.27 to 0.40% [52] 1.08 to 1.85 % [49, 53].

Protein content

The protein content and kernel hardness has been reported to be the best suited classification tools to classify the wheats into hard red spring and hard red winter wheats [54]. The dough containing more protein content expanded at a faster rate than those containing less protein contents, during proofing for expanded period. The differences in dough expansion rate are attributed to the effect of flour protein on dough extensibility [55]

The protein content is not only a factor assessing the end use property but it can also influence the baking properties of both hard wheat flour [56] and soft white wheat flour [57]. Wheats having high protein content (hard wheat) get premium price in the market as they are useful in blending with low protein wheat (soft wheat) flours for bread production. Flours of low protein content wheats are useful in making other different products like cakes, cookies and biscuits [58]. The protein content has been found to be correlated with the gluten content [59].

Butt *et al.* [60] evaluated thirty wheat varieties and found that moisture content, crude protein, crude fibre and ash content differed significantly ($P \leq 0.01$) among the wheat varieties. The protein, fiber and ash contents varied from 10.74 to 13.16%, 2.16 to 2.63% and 1.14 to 1.61%, respectively during 1993-94 crop years and for the crop year 1994-95 these varied between 10.82 to 13.23%, 2.09 to 2.98% and 1.03 to 1.64%, respectively

Ahmad [61] found that the moisture, ash, crude protein, crude fat, crude fibre, nitrogen free extract, wet gluten and dry gluten ranged from 9.38 to 10.43%, 1.32 to 1.85%, 10.13 to 14.74%, 1.96 to 2.52%, 2.31 to 2.99%, 78.71 to 85.37%, 23.53 to 38.71% and 7.51 to 13.52%, respectively among wheat varieties. In Pakistan the protein content ranged from 10.43 to 14.74% in different wheat varieties grown under identical conditions [53, 62, 63].

Wet and Dry gluten

The gluten content is an important parameter in assessing the quality of wheat flour [64, 65]. The flour quality is mainly affected by the nature of the gluten and its various components. The gluten is formed due to the interaction of the glutenin and gliadin protein fractions, which is also associated with pentosans during dough [66] The term ‘gluten’ refers to the proteins, because they play a key role in determining the unique baking quality of wheat by conferring water absorption capacity, cohesiveness, viscosity and elasticity on dough. The gluten, roughly comprising 78 to 85% of total wheat endosperm protein, is a very large complex composed mainly of polymeric (multiple polypeptide chains) and monomeric (single chain polypeptides) proteins known as glutenins and gliadins, respectively [67]. Zeleny and SDS-sedimentation tests are currently and most widely

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employed as rapid tests to screen early generation wheat lines for bread making quality [24]. The weak dough with an extensive gluten network is suitable for bread making [36] whereas weak dough without an extensive gluten network is suitable for cookies and cakes production [68].

The gluten has also been found to significantly affect the baking quality of wheat flour [3]. The higher molecular weight glutenins exhibited positive correlation with excessive mixing time requirement [69]. The mixing strength is correlated with dough stability [70].

The gluten has a correlation with total protein, albumins and insoluble protein contents. The dough development time increased with increase in total and true soluble pentosans and high activity of proteolytic enzyme. The dough stability also showed an increase with increase in gluten content and proteolytic enzyme activity.

The approach to wheat protein quality is based on considering potential end product. Gluten quality varies and is based on varietal characteristics. The wet and dry gluten contents vary widely among the wheat varieties [71]. Paliwal and Singh [71] reported variation in flour yield from 55.48 to 72.56%, wet gluten 12.77 to 44.06 %, ash 0.39 to 0.78 %, crude fibre 0.27 to 0.97 %, sedimentation value 17 to 35.3 ml, damaged starch 2.8 to 5.7 % and pelshenke value 82-133 minutes for different wheat varieties. Specific volume of breads prepared from 100 gm of white flour of different wheat varieties varied from 2.93 to 3.75 cc g^{-1}.

SDS-sedimentation test

The sedimentation test is a measure of the strength of wheat and depends on the degree of hydration of the proteins and their degree of oxidation. The addition of the mild detergent, sodium dodecyl sulphate (SDS) facilitates the hydration of proteins because the gluten molecules are associated with oil bound molecules. For this test ground flour sample is shaken in the presence of lactic acid and SDS [37]. The proteins with good hydration capacity and good oxidation status are obtained from a stable suspension and the height of suspension has linear relationship with the strength and baking potential of the wheat. Sedimentation volume is a measure of baking quality of the flour protein [72] The higher the SDS value, the higher the potential baking strength of wheat flour [37] The SDS sedimentation value possesses the greatest potential as a screening test because of its small sample size, high through put, good correlation with loaf properties, growing sites and genetic differences in protein quality. Therefore SDS may be directly related to bread making potential [73].

Falling number

Falling Number test measures the α-amylase activity. Falling Number test is applicable for flour [74] α-amylase is an inherent enzyme of wheat which converts starch into simple sugars. Falling Number value is critical for final product because there is direct relationship between α-amylase activity and finished product attributes e.g. bread crumb quality and loaf volume [75]. α-amylase is an inherent enzyme of wheat which converts in to simple sugars. Proper amount of α-amylase (FN=250) in the flour is desirable for proper baking to occur. Falling Number value of greater than 250 is generally acceptable for bread making. Adequate α-amylase activity in flour results high volume bread with firm and soft texture [76]. Flour having high α-amylase activity (low FN) requires less amount of water for mixing, softens the dough, weakens the bread structure and produces a soft sticky crumb having low loaf volume [77]. On the other hand, excessive amylase activity (low FN) converts more starch into dextrin and gummy substances during cooking and makes bread sticky and unattractive [78]. Excessive α-amylase activity (low FN) results in the formation of darkened loaf crust as a result of sugar caramalization and sticky crumb structure which causes problems during slicing [47]. Millers prefer to avoid wheat with excessive α-amylase activity (low FN) [76]. High α-amylase activity reduces the water holding capacity of the flour and weakens the bread crumb [59] observed Falling number values exceeding 400 seconds and high starch paste viscosities as determined by RVA indicated low α-amylase activity were possessed by Pakistani wheat cultivars. Bread-baking quality was found to be better in some Pakistani wheat cultivars (Pak 81 and Faisalabad 85) than other wheat cultivars.

RHEOLOGICAL CHARACTERISTICS

The rheology of wheat flour dough is influenced by the wheat proteins. The physical dough properties, especially those coupled with dough baking properties are mainly assessed by the glutenin proteins [79]. The fitness of wheat flour for making products like chapattis, bread and biscuits depends largely on the particular rheological dough properties such as stability, extensibility, development time etc. The rheological properties of the dough are determined by farinograph, mixograph, extensograph etc [80].

The water absorption capacity is the most important physical parameter affecting the farinogram, and is a function of the wheat flour protein content and quality [2] The absorption is the amount of water required to counter the farinograph curve on the 500-Brabender Unit line for dough. The flour with higher water absorption gives more favorable end products because it improves the texture and grain of the bread [81]

Anjum [82] observed that some Pakistani wheats are more stable than U.S. wheats and farinographic characteristics of Pakistani wheat Barani 83 showed a significantly longer mixing time and stability over U.S wheat. Faisalabad 83 was found to have weak gluten quality characteristics as indicated by farinographic studies. The low protein wheats (less than 12%) require long mixing time and certain chemical agents particularly reducing agents lead to shorter the mixing time. The lower pH gives lower while high pH gives higher mixing time [66]. Bean [83] reported that farinograph curve characteristics for any given wheat cultivar changes from location to location. The weather and soil conditions affect the protein content and wheat quality and indirectly the shape of the farinographic curve. Direct correlation between flour protein and mixing strength does not always exist. Kunerth and Appolonia [84] evaluated over 240 hard red spring wheats and reported little or no relationship between wheat protein content and peak mixing time, dough stability and mixing tolerance index.

CONCLUSION

The quality of wheat is generally assessed on the basis of different physical, chemical, biochemical and rheological properties. The products prepared from wheat grains require different quality characteristics. The wheat flour’s ability to be processed into different food products is mainly determined by the quantity and quality of its constituents. The quality of wheat is governed by the interaction of many constituents; therefore it is difficult to assess quality of wheat by any single test. Test baking is not always possible, especially for a large number of samples or where only small amounts of whole meal are available. Therefore, there is a dire need to develop rapid and sensitive tests to assess the chapatti making and bread making quality of wheat varieties. An important choice to this may be Enzyme-Linked Immunosorbent Assay (ELISA). The application of immunological methods to study and compare the cereal proteins from different species actually excludes the use of various chemical and rheological tests. Immunochemical quality assessment through immunological methods can provide a vital tool in measuring functionality and suitability of different wheat varieties for chapatti and bread making quality.

REFERENCES

[1] Halverson, J. and L. Zeleny (1988) Criteria of wheat quality. In: Wheat Chemistry & Tech. (Y. Pomeranz, ed.). American Association of Cereal Chemist. Inc., St. Paul, MN. pp 15-46

[2] Finney, K.F., W.T. Yamazaki, V.L. Youngs and G.L. Rubenthaler (1987) Quality of Hard, Soft and Durum wheats. In: Wheat and Wheat Improvement. 2nd Edition. E.G. Geyne, Ed. Agronomy Monograph No. 13, Medison, WI., pp 667-748

[3] Kent, N.L. and A.D. Evers (1994) Technology of cereals. 4th ed. Pergamon Press, Oxford.

[4] Misra, B.K., and R.K. Gupta (1995) Protocols for evaluation of wheat quality. Directorate of Wheat Research, Karnal, Haryana, India. Technical Bulletin 3: 4- 10

[5] Menjivar, J.A. (1990) Fundamental aspects of dough rheology 1-28 in: Dough rheology and baked product texture. H.Faridi and JM Faubion, eds Avi: NY.

[6] Cornell, J.H. and A.W. Hoveling (1998) Wheat chemistry and utilization. Technomic Pub. Co., Inc. Lancaster. pp. 7

[7] Souza, E., M. Kruk and D.W. Sundarman (1994) Association of sugar snap cookie quality with high molecular weight glutenin alleles in soft white spring wheats. Cereal Chem, 71:601-605

[8] Dexter, J.E., R.R. Matsuo and A.W. MacGregor (1985) Relationship of instrumental assessment of spaghetti cooking quality to the type and the amount of material rinsed form cooked spaghetti. J Cereal Sci, 3:39-53

[9] Pena, R.J. (1997) Wheat quality for bread food needs. In: Nagarajan S, Singh G and Tyagi BS (eds.) Proceedings of International meeting on “Wheat research needs beyond 2000AD”, Directorate of Wheat Research, Karnal, India, 28:303-312

[10] Sontag-Strohm, T., P.I. Payne, and H. Salovaara (1996) Effect of allelic variation of glutenin subunits and gliadins on baking quality in the progeny of two biotypes of bread wheat cv. Ulla. J Cereal Sci, 24:115-124

[11] Southan, M. and F. MacRitchie (1999) Molecular weight distribution of wheat proteins. Cereal Chem, 76:827–836

[12] Cox, T.S., J.P. Shroyer, L. Ben-Hui, R.G. Sears and T.J. Martin (1988) Genetic improvement in agronomic traits of hard red winter wheat cultivars from 1919 to 1987. Crop Sci, 28:756

[13] Pates, M. (1988) U.S. Agricultural official wants emphasis on wheat quality. Trading Trends 9:1

[14] Kosmolak, F.G., J.E. Dexter, R.R. Matsuo, D. Leslie and B.A. Marchylo (1980) A relationship between durum wheat quality and gliadin electrophoregrams. Can J Plant Sci, 60:427-432

[15] Bietz, J.A. (1983) Separation of cereal proteins by reversed-phase high performance liquid chromatography. J Chromatogr 255:219-238

[16] Tronsmo, K.M., E.M. Faergestad, A. Longva, J.D. Schofield and E.M. Mgnus (2002) A study of how size distribution of gluten proteins, surface properties of gluten and dough mixing properties relate to baking properties of wheat flours. J Cereal Sci, 35(2):201-214

[17] Gaines, C.S., P.F. Finney, L.M. Fleege and L.C. Andrews (1996) Predicting a hardness measurement using the single-kernel characterization system. Cereal Chem, 73:278-283

[18] Liming, H., R.S. Zenetra, and D. Birzer (1991) Wheat genotype and environment effects on cheese steamed breadquality. Crop Sci, 31:1279-1282

[19] Peterson, C.J., R.A. Graybosch, P.S. baenziger and A.W. Grambacher (1992) Genotype and environment effects on quality characteristics of hard red white wheat. Crop Sci, 32:98-103

[20] Payne, P.I., G.K. Lookhart and S.A. Forsyth (1988) Short communications. The high molecular weight glutenin subunit composition of two closely related lines of wheat that have contrasting breadmaking quality. J Cereal Sci, 8:285-288

[21] Lill, V.D. and J.L. Purchase (1995) Directions in breeding for winter wheat yield and quality in South Africa from 1930 to 1990. Euphytica, Netherlands, 82:79-87

[22] Faridi, H. (1990) Report on the two year study on soft wheat quality attributes affecting cookie and cracker texture. Presented at the B and CMA Technical Conference, October 28-30, Orlando, available through B and CMA office, Washington, D.C.

[23] Peltonen, J. and A. Virtanen (1994) Effect of nitrogen fertilizers differing in release characteristics on the quality of storage proteins in wheat. Cereal Chem, 71:1-5

[24] Weegels, P.L., A.M. van de Pijpekamp, A. Graveland, R.J. Hamer and J.D. Schofield (1996) Depolymerisation and re-polymerisation of wheat glutenin during dough processing. I. Relationships between glutenin macropolymer content and quality parameters. J Cereal Sci, 23:103-111

[25] Martinant, J.P., Y. Nicolas, A. Bouguennec, Y. Popineau, L. Saulnier, G. Branlard (1998) Relationships between mixograph parameters and indices of wheat grain quality. J Cereal Sci, 27:179–189

[26] Pechanek, U., A. Karger, S. Groger, B. Charvat, G. Schoggl and T. Lelley (1997) Effect of nitrogen fertilization on quantity of flour protein components, dough properties, and bread making quality of wheat. Cereal Chem, 74(6):800-805

[27] Veraverbeke, W.S. and J.A. Delcour (2002) Wheat protein composition and properties of wheat glutenin in relation to breadmaking functionality. Critical Rev Food Sci Nutri, 42:179-208

[28] Bergman, C.J., D.G. Gualberto, K.G. Campbell, M.E. Sorrells and P.L. Finney (1998) Genotypic and environment effects on wheat quality traits in a population derived from a soft by hard cross. Cereal Chem, 75(7):729-737

[29] Peterson, C.J., R.A. Graybosch, D.R. Shelton and P.S. Baenziger (1998) Baking quality of hard winter wheat: Response of cultivars to environment in the great plains (Reprinted from wheat: Prospects for global improvement 1998). Euphytca, 100(1-3):157-162

[30] Lafiandra, D., S. Masci, C.S. Blumenthal and C.W. Wrigley (1999) The formation of glutenin polymer in practice. Cereal Foods World 44:572-578.

[31] Hook, S.C.W. 1984. Specific weight and wheat quality. J Sci Food Agric, 35:1136

[32] Stenvert, N.L. and K. Kingswood (1977) The influence of the physical structure on protein matrix on wheat hardness. J Sci Food Agric, 28:11-19

[33] Habernicht, D., J.M. Martin and L.E. Talbert (2002) End-use quality of hard red and hard white spring wheat contaminated with grain of contrasting classes. Cereal Chem, 79(3): 404-407

[34] Curioni A, N.E. Ponga, G. Pasini, P. Spettoli, M. Voltarel and A. Dal Belin Peruffo (2000) Characterisation of the glutenin fraction from eikorn wheat (Triticummonococum SSP.Mononcoccum) with different bread making qualities. Italian J Food Sci, 12:91–102

[35] Sivri, D., H.D. Sapirstein, W. Bushuk, and H. Koksel (2001) Wheat intercultivar differences in susceptibility of glutenin protein to effects of bug (*Eurygaster integriceps*) protease. Cereal Chem, 79 (1):41-44

[36] Pomeranz, Y. (1990) Advances in cereal sciences and technology. Deptt. Food Sci. and Human Nutr. Pub. American Assoc. of Cereal Chemists, Incorporated. St. Paul, Minnosota, USA.

[37] Williams, R., F.J. El-Haramein, H. Nakkoul and S. Rihawi (1986) Crop quality evaluation methods and guidelines. Technical manual 16. Int. Cent. Agric. Res. Dry Areas, P.O. Box 5466, Aleppo, Syria.

[38] Monsalve-Gonzalez, A. and Y. Pomeranz (1993) Effect of spring and winter growth habitat on compositional, milling, and baking charcteristics of winter wheats. Cereal Chem, 70:354

[39] Hlynka, I. and W. Bushuk (1959) The weight per bushel. Cereal Sci, 4:239

[40] Shuey, W.C. (1960) A wheat sizing technique for predicting flour milling yield. Cereal Sci, 5:71-72

[41] Schuler, S.F., R.K. Bacon, P.L. Finney and E.E. Gbur (1995) Relationship of test weight kernel properties to milling and baking quality in soft red winter wheat. Crop Sci 35:449

[42] Marshal, D.R., Mores, D.J., F.W. Ellison (1986) Effect of grain shape and size on milling yields in wheat.II. Experimental studies. Aus J Agric Res 35: 619

[43] Donelson, J. R., C. S. Gaines, L. C. Andrews and P. F. Finney (2002) Prediction of test weight from small volume specific gravity measurement. Cereal Chem, 79(2):227-229

[44] Zanetti, S., M. Winzeler, C. Feuillet, B. Keller and M. Messmer (2001) Genetic analysis of bread-

making quality in wheat and spelt. Plant Breeding, 120:13-19

[45] Anjum, F.M., N. Ahmad, M.S. Butt and I. Ahmad (2002) Phytate and mineral contents in different milling fractions of some Pakistani spring wheats. Int J Food Sci Tech, 37:13-17

[46] Baril, C.P. (1992) Factor regression for interpreting genotype-environment interaction in bread wheat trials. Theor Appl Genet, 83:1022-1026

[47] Gooding, M. J. and W. P. Davies (1997) Wheat Production and Utilization: Systems, Quality and the Environment. CAB Int., Wallingford

[48] Whiteley, R. (1970) Biscuit Manufacture Applied Science Pub. Ltd. London.

[49] Butt, M.S., F.M. Anjum, J.V.Z. Dick and S. Mumtaz (2001) Development of predictive models of end-use quality of spring wheats through canonical analysis. Int J Food Sci Tech, 36:433-440

[50] Hruskova, M. and O. Famera (2003) Prediction of wheat and flour Zeleny sedimentation value using NIR technique. Czech J Food Sci, 21:91–96

[51] Dowell, F.E., T.C. Pearson, E.B. Maghirang, F. Xie and D.T. Wicklow (2002) Reflectance and transmittance spectroscopy applied to detecting fumonisin in single corn kernels infected with *Fusarium verticillioides*. Cereal Chem, 79:222-226

[52] Yamamoto, H., S.T. Worthington, G. Hou, and P.K.W. Ng (1996) Rheological properties and baking qualities of selected soft wheats in the United States. Cereal Chem, 73:215-221

[53] Ahmad, I., F.M. Anjum and M.S. Butt (2001) Quality characteristics of wheat varieties grown in Pakistan from 1933-1996. Pak J Food Sci 11:1-4

[54] Slaughter, C.D., H.N. Kari and R.H. William (1992) Quality and classification of hard red wheat. Cereal Chem, 69:428

[55] He, H. and R.C. Hoseney (1992) Effect of quantity of wheat flour protein on bread loaf volume. Cereal Chem, 69:17-19

[56] Orth, R.A. and W. Bushuk (1972) A comparative study of the proteins of wheats of diverse baking qualities. Cereal Chem, 49:268-275

[57] Kaldy, M.S. and G.L. Rubenthaler (1987) Milling, baking, and physical-chemical properties of selected soft white winter and spring wheats. Cereal Chem, 64:302-307

[58] Hoseney, R.C., P. Wadwand and J.W. Finley (1988) Soft wheat products. In: Wheat Chemistry and Technology vol. 2 (Y. Pomeranz, ed.), American Association of Cereal Chemists, St. Paul, Inc. MN. pp. 407-456

[59] Anjum, F. M. and C. E. Walker (2000) Grain, flour and bread-making properties of eight Pakistani hard white spring wheat cultivars grown at three different locations for 2 years. Int J Food Sci Tech, 35(4):407-416

[60] Butt, M.S., F.M. Anjum, A. Rehman and A. Ali (1997) Physico-chemical characteristics of spring wheats. J Agric Res, 35(6):413-422

[61] Ahmad, I. (2001) Varietal differences in amino acid, composition, milling and baking properties of spring wheats. Ph.D. Thesis, Deptt. Food Tech., Univ. of Agric., Faisalabad, Pakistan.

[62] Butt, M.S., M.I. Qamar, F.M. Anjum, A. Aziz and M.A. Randhawa (2004) Development of minerals-enriched brown flour by utilizing wheat milling by-products. Nutri Food Sci, 34 (4):161-165

[63] Anjum, F.M., I. Ahmad, M.S. Butt, M.A. Sheikh and I. Pasha (2005) Amino acid composition of spring wheats and losses of lysine during chapatti baking. J Food Comp Anal, 18: 523-532

[64] Grabski, J., U. Tycznska and A. Iskupski (1979) Possibility of determining the baking properties of flour for manufacture of sweet biscuits. Przeglad Piekarskii Cukierniczy, 27(7):133-134

[65] Kulkarni, R.G., J.G. Ponte and K. Kulp (1987) Significance of gluten content as an index of flour quality. Cereal Chem, 64:1-3

[66] Hoseney, R.C. (1986) Yeast leavened products. In: Principles of Cereal Science and Technology. American Association of Cereal Chemists Inc., St. Paul, MN. pp. 203.

[67] Wieser, H. and R. Kieffer (2001) Correlations of the amount of gluten protein types to the technological properties of wheat flours determined on a micro-scale. J Cereal Sci, 34(1):19-27

[68] Gaines, C.S. (1990) Influence of chemical and physical modification of soft wheat protein on sugar snap cookie dough consistency, cookie size and hardness. Cereal Chem, 67:73

[69] Khan, K., G. Tamminga and O.M. Lukow (1989) The effect of wheat flour proteins on mixing and baking correlations with protein fraction and high molecular weight glutenin subunit composition by gel electrophoresis. Cereal Chem, 66:391-396

[70] Bietz, J.A. (1986) High performance liquid chromatography of cereal proteins. In Advances in cereal science and technology. Vol 8 (Y. Pomeranz, ed.): American Association of Cereal Chemists, St. Paul, Inc. MN. pp 105-107

[71] Paliwal, S.C. and G. Singh (1985) Physico-chemical, milling and bread making quality of wheats of Uttar Pradesh. Deptt. Food Sci. Tech., G. B. Pant Univ. Agri. Tech., Pantnagar, India

[72] Zeleny, L. (1947) A simple sedimentation test for estimating the bread baking and gluten qualities of wheat flour. Cereal Chem, 24:465-475

[73] Blackman, J.A. and A.A. Gill (1980) A comparison of some small scale tests for bread making quality used in wheat breading. J Agric Sci, 95:29-34

[74] Huebner, F.R., T.C. Nelsen and J.A. Bietz (1995) Differences among gliadins from spring and winter wheat cultivars. Cereal chem., 72(4):341-343

ISSN: 0975 - 4539
IJBSAT (2010), 2(2):12-20

[75] Perten, H. (1964) Application of the falling number method for evaluating alpha amylase activity. Cereal Chem, 41: 127-140

[76] Muller, S., W.H. Vensel, D.D. Kasarda, P. Köhler and H. Wieser (1998) Disulphide bonds of adjacent cysteine residues in low molecular weight subunits of wheat glutenin. J Cereal Sci, 27:109-116

[77] Coskuner, Y. and E. Karababa (2005) Studies on the quality of Turkish flat breads based on blends of triticale and wheat flour. Int J Food Sci Tech 40:469–479

[78] Zeleny, J. (1963) Hemerobiidae [Neuroptera] from Czechoslovakia. Asopis Eskosl Spon Ent, 60(4): 55-67

[79] Fowler, D.B., and I.A. De La Roche (1975) Wheat quality evaluation. 3 influence of genotype and environment. Can J Plant Sci, 55: 263

[80] Austin, A. and A. Ram (1971) Studies on chapati-making quality of wheat. Indian Council of Agricultural Research, Tech. Bull. No. 31, ICAR: New Delhi.

[81] Baixuli, R., T. Sanz, A. Salvador and S.M. Fiszman (2007. Influence of the dosing)process on the rheological and microsrtuctural properties of a bakery product. Food Hydrocolloids, 21(2):230-236

[82] Anjum, F.M., I. Ahmad, M.S. Butt and M.U. Arshad (2008) Improvement in end-use quality of spring wheat varieties grown in different varieties grown in different areas. Food Chem, 106:482–486

[83] Bean, S. R. and G.L. Lookhart (2000) Ultrafast capillary electrophoresis analysis of cereal storage proteins and its applications to protein characterization and cultivar differentiation. J Agric Food Chem, 48:344-353

[84] Kunerth, W.H. and B.L.D Appolonia (1985) Use of the mixograph and farinograph in wheat quality evaluation. In: H. Faridi, Editor, Rheology of Wheat Products, AACC, St.Paul, pp. 27–49